UNIVERSITI SAINS MALAYSIA

Study on the Extent of Removal of Copper, Zinc, Iron, Lead, and Chromium Ions in Tap Water by Tea Leaves

Dissertation Submitted in Partial Fulfillment for the
Degree of Bachelor of Science (Health) in Forensic Science

Noor Asyikin bt. Hj. Suaidi

School of Health Sciences
University Sains Malaysia
Health Campus
16150 Kubang Kerian, Kelantan,
Malaysia

2007

CERTIFICATE

This is to certify that the dissertation entitled

"Study on the Extent of Removal of Copper, Zinc, Iron, Lead, and Chromium Ions in Tap Water by Tea Leaves"

is the bonafide record of research work done by

Ms. Noor Asyikin binti Hj. Suaidi

during the Period of **December 2006** to **March 2007**

under my supervision.

Signature of Supervisor :

Name and Address of Supervisor : Dr. K.D. Henry

School of Health Sciences

Universiti Sains Malaysia (USM)

16150 Kubang Kerian

Kelantan

Date : 10th May 2007

ACKNOWLEDGEMENTS

The completion of this final year project requires strong constant guidance of supervisor, cooperation from administration, as well as encouragement and support from colleagues and friends.

First of all, I would like to express my gratefulness to the Almighty God for giving me the chance and time to finish this research project.

I would like to express my special thanks to my project supervisor, Dr. K.D. Henry for his guidance and support throughout this project as well as for keeping me from veering off course.

I would also like to convey my appreciation to the scientific officers; Puan Norazizah Abdullah, Puan Hafizah Harun, Encik Rosliza Haron, and Puan Siti Zabedah for being supportive and cooperative in dealing with the protocols and materials required for this project. Things wouldn't have run smoothly without them.

I extend special thanks to Encik Wan Sahnusi for helping me with the instrumental aspect of this project; operating the Atomic Absorption Spectrophotometer (AAS) machine which is a critical aspect of my research project.

My gratitude is also extended to Pn. Rosniah for being very helpful fulfilling my needs when doing my works in the Forensic Laboratory.

A sincere appreciation I would like to express to all staff in Unit Kemudahan Makmal for their cooperation when dealing with the equipments and reagents for this project.

A specific acknowledgement and grateful appreciation goes to my friends, Seri Mirianti Ishar, Siti Aisyah Mualif, and Muhd. Yusmaidi Aziz, and whom I spent my extra time with in the Forensic Laboratory after office hours. Their company had allowed my work to finish earlier than expected.

Finally, I would like to thank everyone who contributed to this final year project; directly or indirectly. Without the support from these people, this project would never be completed successfully.

CONTENTS

LIST OF TABLES AND FIGURES

List of Tables **Page**

List of Figures

ABSTRACT

It has been suggested that tea bags and tea leaves are capable of removing certain amount of heavy metals from water, based on a study conducted using the coffee grounds. A study on the extent of removal of copper, zinc, lead, iron, and chromium ions from tap water using different types of tea leaves has been demonstrated. Tap water is known to contain certain level of concentration of these metals. The concentrations of copper, zinc, lead, iron, and chromium in the tap water from selected sources were determined by atomic absorption spectrometer (AAS). Using the same tap water, tea extracts were obtained by preparing tea using selected tea leaves. The extracts were subjected to acid digestion before being analyzed using AAS for the above metals. The concentrations of copper, zinc, lead, iron, and chromium before and after preparation of tea were compared. Certain amount of the metals of concern was expected to be removed after tea preparation. Results from analysis demonstrated that tea bags removed copper, zinc and lead from the tap water by 29.0%, 31.3%, and 46.7% respectively. Large tea leaves, the oolong tea has been shown to remove copper, zinc, and lead by 54.0%, 48.0%, and 37.7% respectively. Fine tea leaves, namely the Ceylon tea removed the above metals by 20.3%, 42.0%, and 41.0% respectively. The concentration of iron and chromium were increased after tea extract preparation. Iron concentrations were increased by 0.190 ppm, 0.205 ppm, and 0.237 ppm in the tea bags, the large tea leaves, and the fine tea leaves respectively, whereas the concentrations of chromium were increased in tea bags, the large tea leaves, and the fine tea leaves by 46.0 ppb, 37.0 ppb, and 43.7 ppb respectively.

INTRODUCTION

Research has been done by the Australian, Chilean and the United States scientists to discover the extent of removal of heavy metals by coffee brewing process and how much the metal was trapped in the coffee grounds. Research by an international team of scientists published in the April 2000 issue of Human and Ecological Risk Assessment has shown that automatic drip coffee makers can remove up to 85% of both copper and lead in tap water (Greene, 2000). Team leader Herbert E. Allen, a professor of civil and environmental engineering at the University of Delaware in Newark, speculates that coffee grounds retain heavy metals through surface chelation, a chemical reaction in which metals form complexes with organic matter. After looking at ion exchange or adsorption as possible filtering mechanisms, he says that due to coffee's nature—coffee grounds having uncharged or negatively charged molecules—surface chelation most likely explains the large percentage of metals removed. Because dissolved heavy metals are positively charged, the metal ions bind strongly to the coffee (Greene, 2000). These scientists also suggested that it is also possible tea-bags and tea leaves may work in the same way, but not as well as coffee. The purpose of this study is to discover the extent of removal of heavy metals in water using tea bags and tea leaves.

Water is one of the most basic needs of mankind. The utilization of water for various activities depends on its physical, chemical, and biological characteristics. This includes public water supply for drinking and domestic purposes, as well as industrial activities. Since drinking water is considered to be the most essential use of water for life,

it must be free of health hazards such as toxins and carcinogens (Tomar, 1999). Water is a universal solvent and so it dissolves most naturally occurring substances as well as those produced by human activities. These substances are found at a wide range of concentrations in water depending on their abundance, solubility and other physicochemical qualities (Tomar, 1999).

Copper

Copper levels in drinking water are usually low at only a few micrograms per liter, but copper plumbing may result in greatly increased concentrations. Concentration can reach several milligrams per liter following a period of stagnation in pipes. Copper is an essential element, and the intake from food is normally 1 – 3 mg/day. In adults, the absorption and retention rates depend on the daily intake; as a consequence, copper overload is unlikely. Acute gastric irritation may be observed in some individuals at concentrations in drinking water above 3 mg/liter. In adults with hepatolenticular degeneration, the copper regulatory mechanism is defective, and long term ingestion can give rise to liver cirrhosis (WHO, 1993)

Zinc

Zinc is an essential trace element found virtually in all food and potable water in the form of salts or organic complexes. The diet is normally the principal source of zinc. Although levels of zinc in surface and ground water normally do not exceed 0.01 and 0.05 mg/liter, respectively, concentrations in tap water can be much higher as a result of dissolution of zinc from pipes. In 1982, Joint FAO/WHO Experts Committee on Food Additives

(JECFA) proposed a provisional maximum tolerable daily intake of zinc of 1 mg/kg of body weight. However, drinking water containing zinc at levels above 3 mg/liter may not be acceptable to consumers (WHO, 1993).

Iron

Iron is one of the most abundant metals in the earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/liter. Iron may also be present in drinking water as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution. Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status, and iron bioavailability and range from about 10 to 50 mg/day. As a precaution against storage in the body of excessive iron, in 1983 JECFA established a provisional maximum tolerable daily intake (PMTDI) of 0.8 mg/kg of body weight. No health-based guideline value for iron in drinking water is proposed (WHO, 1993).

Lead

Lead is used principally in the production of lead-acid batteries, solder, and alloys. Owing to the decreasing use of lead-containing additives in petrol and lead containing solder in the food processing industry, concentrations in air and food are declining, and intake from drinking water constitutes a greater proportion of total intake. Lead is present in tap water to some extent as a result of its dissolution from natural sources, but primarily from household plumbing systems containing lead in pipes, solder, fittings, or the service connection to homes. The amount of lead dissolved from the plumbing system

depends on several factors, including pH, temperature, and water hardness (WHO, 1996). Lead can cause a variety of adverse health effects in humans. At relatively low levels of exposure, these effects may include interference with red blood cell chemistry, delays in normal physical and mental development in babies and young children, slight deficits in the attention span, hearing, and learning abilities of children, and slight increases in the blood pressure of some adults. It appears that some of these effects, particularly changes in the levels of certain blood enzymes and in aspects of children's neurobehavioral development, may occur at blood lead levels as low as to be essentially without a threshold. Chronic exposure to lead has been linked to cerebrovascular and kidney disease in humans (USEPA, 2006).

Chromium

Chromium is widely distributed in earth's crust. It can exist in valences of +2 to +6. Total chromium concentrations in drinking water are usually less than 2µg/liter, although concentrations as high as 120µg/liter have been reported. In general, food appears to be the major source of intake (WHO, 1993). The absorption of chromium after oral absorption is relatively low and depends on the oxidation states. Chromium (VI) is more readily absorbed from gastrointestinal tract than chromium (III) and is able to penetrate cellular membranes. There are no adequate toxicity studies to provide a basis for a "No-observed-adverse-effect-level" (NOAEL). In a long term carcinogenicity study in rats, chromium (III) given by the oral route, no increase in tumor incidence was observed. In rats, chromium (VI) is a carcinogen via the inhalation route, although the limited data available do not show evidence for carcinogenicity via the oral route. In epidemiological

studies, an association has been found between exposure to chromium (VI) by the inhalation route and lung cancer. IARC has classified chromium (VI) in Group 1 (human carcinogen) and chromium (III) in Group 3. In principle, it was considered that different guideline values for chromium (III) and chromium (VI) should be derived (WHO, 1993). Because of the carcinogenicity of chromium (VI) by the inhalation route and its genotoxicity, the current guideline value of 0.05 mg/liter, which is considered to be unlikely to give rise to significant risks to health, has been retained as the provisional guideline value until additional information becomes available and chromium can be re-evaluated.

The Tea Plants

Tea is one of the most widely consumed beverages in the world today, second only to water, and its medicinal properties have been widely explored. The tea plant, Camellia *sinensis*, is a member of the Theaceae family, and black, oolong, and green tea are produced from its leaves. It is an evergreen shrub or tree and can grow to heights of 30 feet, but is usually pruned to 2-5 feet for cultivation. The leaves are dark green, alternate and oval, with serrated edges, and the blossoms are white, fragrant, and appear in clusters or singly. Unlike black and oolong tea, green tea production does not involve oxidation of young tea leaves. Green tea is produced from steaming fresh leaves at high temperatures, thereby inactivating the oxidizing enzymes and leaving the polyphenol content intact. The polyphenols found in tea are more commonly known as flavanols or catechins and comprise 30-40 percent of the extractable solids of dried green tea leaves. The main catechins in green tea are epicatechin, epicatechin-3-gallate, epigallocatechin,

and epigallocatechin-3-gallate (EGCG), with the latter being the highest in concentration (Painter, 2000).

The tea plant *C. sinensis* (Figure 1) is native to Southeast Asia but is currently cultivated in >30 countries around the world. Of the total amount of tea produced and consumed in the world, 78% is black, 20% is green, and <2% is oolong tea. Black tea is consumed primarily in Western countries and in some Asian countries, whereas green tea is consumed primarily in China, Japan, India, and a few countries in North Africa and the Middle East. Oolong tea production and consumption are confined to southeastern China and Taiwan (Mukhtar and Ahmad, 2000).

Figure 1: Camelia sinensis (Source: http://en.wikipedia.org/wiki/Tea_plant)

Green tea, black tea, and oolong tea are all derived from the same plant (Ethan and Catherine, 2005). They undergo different manufacturing processes. To produce green tea, freshly harvested leaves are rapidly steamed or pan-fried to inactivate enzymes, thereby preventing fermentation and producing a dry, stable product. Epicatechins are the main compounds in green tea, accounting for its characteristic color and flavor. For the

production of black and oolong teas, the fresh leaves are allowed to wither until their moisture content is reduced to approximately 55% of the original leaf weight, which results in the concentration of polyphenols in the leaves. The withered leaves are then rolled and crushed, initiating fermentation of the polyphenols. During these processes, the catechins are converted to theaflavins and thearubigins. Oolong tea is prepared by firing the leaves shortly after rolling to terminate the oxidation and dry the leaves. Normal oolong tea is considered to be about half as fermented as black tea. The fermentation process results in oxidation of simple polyphenols to more complex condensed polyphenols to give black and oolong teas their characteristic colors and flavors (Mukhtar and Ahmad, 2000).

This study will investigate whether the tea bags and tea leaves are capable of removing certain heavy metals from tap water and the extent of their removal will be demonstrated by determining the metal concentration in the tap water before and after preparation of tea extracts.

REVIEW OF LITERATURE

Research and studies on the extent of removal of heavy metals in water using tea leaves are limited and most studies that had been conducted so far were to discover the efficacy of tea waste and other bio-waste and plant materials for waste water treatment (Kumar, 2006, Gardea-Torresdey et al, 2004). Others involve the effectiveness of living plants in removal of heavy metal contaminants from soil and water by up taking these metals from various plant parts (phytoremediation).

Water pollution due to toxic heavy metals has been a major cause of concern for environmental engineers. The industrial and domestic wastewater is responsible for causing several damages to the environment and adversely affecting the health of the people. Several episodes due to heavy metal contamination in aquatic environment increased the awareness about the heavy metal toxicity (Kumar, 2006). A variety of industries are responsible for the release of heavy metals into the environment through their wastewater (Braukmann, 1990). These include iron and steel production, the non-ferrous metal industry, mining and mineral processing, pigment manufacture, the painting and photographic industries and metal working and finishing processes (electroplating). In addition, considerable quantities of heavy metals can be released into the environment through routes other than wastewater. For example, lead is widely used in metallic form and copper is used in electric equipment, water pipes, alloy, as chemical catalysts and in anti-fouling paints in ship hulls.

The use of agricultural products and by-products has been widely investigated as a replacement for current costly methods of removing heavy metals from water and wastewater (Kumar, 2006). Some of the agricultural materials can be effectively used as a low-cost sorbent. Modification of agricultural by-product could enhance their natural capacity and add value to the by-product (Kumar, 2006). The main techniques, which have been utilized to reduce the heavy metal ion content of effluents, include lime precipitation, ion exchange, adsorption into activated carbon (Dean et al., 1972), membrane processing, and electrolytic methods (Braukmann, 1990).

Agrowastes are currently receiving attention as raw materials for water pollution control because of their low cost and availability. A range of products, such as clay, sago waste, cassava waste, banana pith, peanut skin, alfalfa and sphagnum moss peat has been examined. These workers have used mostly divalent metal ions (Michael and Ayebaemi, 2004).

A wide variety of agricultural and forestry by products have been used as biosorbents of toxic metals in a bid to develop biofilters for specific applications, such as the use of waste tea leaves to filter lead (Pb), cadmium (Cd) and zinc (Zn) (Prasad and Freitas, 2003). In a study conducted by Orhan and Buyukgungor (1993), the adsorption capacity of waste tea for cadmium (Cd^{+2}) and chromium (Cr^{+6}) was 1.63 mg/g and 1.55 mg/g respectively (Table 1).

Material	Adsorption capacity (mg/g)						References
	Cd^{+2}	Cr^{+3}	Cr^{+6}	Hg^{+2}	Pb^{+2}	Zn^{+2}	
Douglas fir bark	-	-	-	100	-	-	Masri et al., 1974
Exhausted coffee	1.48	-	1.42	-	-	-	Orhan and Buyukgungor, 1993
Waste tea	1.63	-	1.55	-	-	-	Orhan and Buyukgungor, 1993
Walnut shell	1.5	-	1.33	-	-	-	Orhan and Buyukgungor, 1993
Untreated pinus sylvestris bark	-	9.69	-	-	-	-	Alves et al., 1993
Treated pinus sylvestris bark	-	9.77	-	-	-	-	Alves et al., 1993
Turkish coffee	1.17	-	1.63	-	-	-	Orhan and Buyukgungor, 1993
Black oak bark	25.9	-	-	400	-	-	Teles and Beca, 1994
Sawdust	-	-	10.1, 16.05 4.44	-	-	-	Bryant et al., 1992 Dikshit, 1989 Zarraa, 1985
Redwood bark	27.6, 32	-	-	250	6.8 182	-	Masri et al., 1974 Randall et al., 1974
Pinus pinaster bark	8	19.45	-	-	3.33, 1.59	-	Teles and Beca, 1993-94 Vazquez et al., 1994
Nut shell	1.3	-	1.47	-	-	-	Orhan and Buyukgungor, 1993
Hardwickia binata bark	34	-	-	-	-	-	Deshkar et al., 1990
Formaldehyde-polymerized peanut skins	74	-	-	-	205	-	Randall et al., 1976
Exhausted coffee	1.48	-	1.42	-	-	-	Orhan and Buyukgungor, 1993
Lignin	-	-	-	-	1965	95	Srivastava et al., 1994
Sulfuric acid lignin	-	-	-	150	-	-	Masri et al., 1974
Xanthate sawdust	21.4	-	-	30.1-40.1	31.1-41.4	-	Flynn et al., 1980
Irish sphagnum moss peat	-	-	119, 43.9	-	-	-	Sharma and Foster, 1993, 1995
Sphagnum moss peat	5.8	29	-	-	40	-	McLelland and Rock, 1988
Rastunsuo peat	5.058	4.63	-	16.2	20.038	-	Tummavuori and Aho, 1980a,b
Modified peat	-	76	-	-	230	-	Kertman et al., 1993
Dry redwood leaves	-	-	-	175	-	-	Masri et al., 1974
Dyed bamboo pulp	-	-	-	15.6	15.0	-	Shukla and Sakhardarre, 1992
Undyed bamboo pulp	-	-	-	9.2	8.4	-	Shukla and Sakhardarre, 1992
Dyed jute	-	-	-	13.7	14.1	-	Shukla and Sakhardarre, 1992
Dyed sawdust	-	-	-	18.0	24.0	-	Shukla and Sakhardarre, 1992
Modified wool	87	-	17	632	135	-	Masri and Friedman, 1974
Moss	46.5	-	-	-	-	-	Low and Lee, 1991
Orange peel (white inner skin)	-	-	125	-	-	-	Masri et al., 1974
Orange peel (outer skin)	-	-	275	-	-	-	Masri et al., 1974
Senna leaves	-	-	250	-	-	-	Masri et al., 1974
Undyed sawdust	-	-	-	8.5	7.3	-	Shukla and Sakhardarre, 1992
Copper-coated moss	-	18.9	7.1	-	-	-	Low and Lee, 1995
Petiolar felt-sheath pf palm	10.9	-	5.32	-	11.4	6.0	Iqbal et al., 2002
Black gram husk	49.74	-	-	-	-	-	Saeed and Iqbal., 2003
Rice husk ash	20.24	-	-	66.66	-	-	Kumar and Bandyopadhyay, 2006
Modified hardwickia binata bark	-	-	-	21	-	-	Deshkar et al., 1999

Table 1: Heavy metal adsorption capacity (mg/g) of agricultural products and by-products (Orhan & Buyukgungor, 1993)

The parameters which have been investigated for optimizing the use of adsorbent in wastewater treatment include nature of adsorbent and adsorbate metal concentration, temperature and pH of the aqueous solution, kinetics of adsorption, adsorption isotherm and the types of contacting system of the adsorbent with the adsorbate and the contact time. The metal adsorption capacities (mg/g) of some of the agricultural product and by-product are compared with activated carbon and some cation exchange resin (Kumar, 2006) as shown in the Table 2 below:

Adsorbent	Pb^{+2}	Cu^{+2}	Zn^{+2}	Cd^{+2}	Ni^{+2}	Hg^{+2}	Cr^{+6}
Granular activated carbon	16.58	5.08	-	3.37	-	-	-
Powdered activated carbon	26.94	4.45	-	3.37	-	-	-
Activated carbon fibers	30.46	11.05	-	-	-	-	-
Peanut hulls	30.04	8.00	8.96	5.96	-	-	-
Corncobs	8.29	7.62	1.96	8.89	13.5	-	-
Cornstarch	28.8	8.57	6.87	8.88	-	-	-
Pine bark	-	9.46	-	14.16	6.28	-	-
Black oak bark	-	-	--	29.9	-	-	-
Lignin	1865	-	95	-	-	-	-
Bark	182	-	-	32	-	400	-
Xanthane	18	-	-	33.27	-	1.149	
Leaf mould	-	-	-	-	-	-	43
Sawdust	-	-	-	-	-	-	16.05
CEPI Cotton		-	-	--	-	1000	-
Duolite GT-73	122.25	61.60	55.59	105.66	56.94	-	-
Amberlite IRC-718	290.08	127.00	156.96	258.32	-	-	-
Amberlite 200	352.24	88.90	85.60	224.8	129.1	-	-
Lewatit TP 207	198.9	85.09	89.60	49.46	88.05	-	-

Table 2: Heavy metal adsorption capacities (mg/g) of some agricultural products compared with activated carbon and some cation exchange resin (Kumar, 2006)

Gardea-Torresdey et al (2004) conducted a study on the use of phytofiltration technologies in the removal of heavy metals using several biomaterials. Biosorption experiments over Cu(II), Cd(II), Pb(II), Cr(III), and Ni(II) demonstrated that biomass Cu(II) adsorption ranged from 8.09 to 45.9 mg g^{-1}, while Cd(II) and Cr(VI) adsorption ranged from 0.4 to 10.8 mg g^{-1} and from 1.47 to 119 mg g^{-1}, respectively. Reported metal adsorption capacities for selected biomaterials are summarized in the Table 3 below:

Material	Cu(II)	Cd(II)	Cr(III)	Cr(VI)	Fe(II)	Fe(III)	Ni(II)	Zn(II)	Pb(II)
Canadian S. peat moss	16.1								
Irish S. peat moss	16.4			119			9.18		
Humic acid	28.2								
Humin	17.9	1.34	8						31.2
Sorghum			10						
Cactus powder	9.5	0.4				0.2	8.3	1.5	2.9
Petiolar palm	8.09	10.8	5.32				6.89	5.99	11.4
Alfalfa	19.7	7.1	7.7		2.88	4.47	4.1	4.9	43
Solanum eleagnifolium	45.9		43.1				13.3	11.5	31.9
Hops									74.2
Cocoa shell									2.58
Pine bark		9.2							
Pine cone		7.5							
Pine needles		7.1							
Nut shell		1.3		1.47					
Paper mill	13.4								

Table 3: Reported metal adsorption capacities (mg/g) for selected biomaterials (Gardea-Torresdey, 2004)

Gaikwad (2001) demonstrated the removal of cadmium (II) from aqueous solution by activated charcoal derived from coconut shell using a batch method. In his study, the coconut shell activated charcoal used in this study was prepared by pulverizing the coconut shell in to the powder in the laboratory pulverizer, washed and dried in oven. It was then kept in furnace up to 600°C for two hours and then stored. A chemical activation was carried out. In chemical activation, degree of impregnation is an important factor. The known quantity of stored coconut shell powder was mixed with barium chloride in the impregnation ratio of 0.5. Required quantity of water was added to the mixture and kept boiling till the water evaporates, then the slurry type mixture was kept in oven at 110°C for 24 hours to remove moisture. The activated charcoal was washed with hydrochloric acid followed by distilled water for about 5 times to remove the activatin. Washed adsorbent was dried at 110°C and then sieved for required size i.e. 200 microns and packed in the polythene bag. The study showed that activated charcoal derived from coconut shell of 30 gm dose could remove the 66% Cd (II) from water.

Although there have been limited studies conducted in demonstrating the effectiveness of tea bags and tea leaves for removing heavy metals from water, there have been suggestions that they are capable of removing heavy metals from the water. Therefore, this study is conducted to investigate the removal of heavy metals from tap water by tea leaves through simple, ordinary preparation of tea.

OBJECTIVE OF STUDY

The objective of the study was to determine the removal of heavy metals; i.e. copper, zinc, iron, lead, and chromium in tap water by using tea leaves. This study was also conducted to establish the extent of removal of the above metals by the selected tea leaves.

It was expected that tea leaves were capable of removing heavy metals of concern from tap water through simple, ordinary preparation of tea as for daily consumptions.

MATERIALS AND METHODS

A. APPARATUS

1. Atomic Absorption Spectrometer (AAS)

Specifications:

- Manufactured by the Perkin Elmer Corporation
- Flame burner with purified acetylene and air as fuel and oxidant
- Flame temperature approximately 2300°C
- Lamps used: Hollow Cathode Lamp (HCL) and Electrodeless Discharge Lamp (EDL)
- Graphite Furnace
- Graphical display and recording system by the instrument's computerized system

2. Glassware

- 250mL and 100mL beakers
- 250mL conical flasks
- 100mL volumetric flasks
- 100mL and 200mL graduated cylinders
- 10mL and 50mL transfer pipettes
- Evaporating dishes
- Glass rods
- Glass funnels

3. Hot plate and magnetic stirrer

4. Filter paper (medium size)

5. Laboratory films (Parafilm)

6. Pipette bulbs

7. Precision Micropipette (100µL, 200µL, and 1000µL) and disposable tips

8. Analytical Balance

B. REAGENTS

1. Reagent water – deionized water and distilled water

2. Concentrated nitric acid (65% nitric acid, HNO_3) manufactured by MERCK

- Percent assay is 65% minimum
- Specific gravity is 1.42

3. 1:1 v/v nitric acid (diluted nitric acid)

- 1:1 v/v nitric acid is prepared by adding concentrated nitric acid to an equal volume of distilled water

4. 1:1 v/v hydrochloric acid (diluted hydrochloric acid, HCl)

- 1:1 v/v hydrochloric acid is prepared by adding concentrated hydrochloric acid to an equal volume of distilled water

5. Stock standard metal solutions

- Commercially available, with concentration of each standard is 1000mg/L
- Stock standards used; copper (Cu), zinc (Zn), iron (Fe), lead (Pb), and chromium (Cr)

C. MATERIALS

1. Tap water samples

- Three tap water samples were used for this research
- Sample collection: Tap water samples from Desasiswa Murni, Pusat Pengajian Sains Perubatan (PPSP) and Kubang Kerian area were collected using polyethylene (PET) bottle of 1.5L each. All samples were collected on 12th December 2006

2. Tea leaves samples

Three types of tea leaves from different types and different particle size were selected for this experiment;

- Oolong Tea (large leaves)
- Ceylon "888" Tea (medium size tea leaves)
- Lipton Yellow Label tea bags

D. METHODS

The study of demonstrating the removal of heavy metals in tap water using tea leaves involved measuring the concentration of copper, zinc, iron, lead and chromium in the tap water before and after the tea preparation. The initial step was to analyze the tap water samples prior to preparation of tea. The second step of the experiment was to prepare the tea using the same water sample to obtain the tea extract. After pre-treatment with nitric acid digestion, the extract was again analyzed and the concentration of the above metals was determined. It was expected that the tea leaves would be able to remove the above mentioned metals at some extent. The instrument used for the experiment was the Atomic Absorption Spectrometer (AAS). Concentration of copper, zinc, and iron were analyzed using Flame AAS, whereas the concentration of lead and chromium were determined using Graphite Furnace AAS.

Determination of Copper, Zinc, Iron, Lead and Chromium in Tap Water

The initial step of the experiment was determination of the concentration of the above metals;

- By direct analysis and
- After nitric acid digestion

The concentration of these metals was determined using Atomic Absorption Spectrometry analysis. The concentration was reported as total recovered metals. All analyses were conducted in duplicates against blank prepared using 1-2% nitric acid.

Nitric acid digestion procedures for Flame AAS and Graphite Furnace AAS (based on the guidelines provided by USEPA method for drinking water analysis) as described below:

- The collected water sample was mixed well and 100mL of the sample was transferred into a 250mL beaker or conical flask
- 2mL of 1:1 v/v of nitric acid (HNO_3) and 10mL of 1:1 v/v hydrochloric acid (HCl) were added to the sample
- The sample was heated on a hot plate or steam bath at a temperature between 92°C – 95°C until the sample was reduced to approximately 25mL, ensuring that sample did not boil
- The sample was left to cool at room temperature
- The sample was transferred into a volumetric flask and the volume is adjusted to 100mL using deionized water
- The sample was ready for AAS analysis

Preparation of standard solutions

- Standards solutions of copper, zinc, iron, lead and chromium were prepared for determination of metal concentration in the tap water.
- For standard preparation of copper, zinc and iron, an accurate volume of the stock standard solution (1000 ppm) was pipetted into a 100mL volumetric flask and made up to the mark using deionized water.
- Serial dilutions were made appropriately according to the desired concentrations of working standards.

- For lead and chromium, standard solution of part per billion (ppb) concentrations were prepared for Graphite Furnace AAS. 10 ml of stock standard solution (1000 ppb) was pipetted into a 100 ml volumetric flask and made up to the mark with deionized water. The prepared solution was used as stock standard.

Table 4: The volume of stock standard solution and its working standard concentration for copper, zinc, iron.

COPPER		
Standard	Volume of Stock Solution (1000 ppm)	Concentration of Standard Working Solution
Standard 1	0.125mL	1.25 ppm
Standard 2	0.25mL	2.5 ppm
Standard 3	0.5mL	5.0 ppm

ZINC		
Standard	Volume of Stock Solution (1000 ppm)	Concentration of Standard Working Solution
Standard 1	0.025mL	0.25 ppm
Standard 2	0.05mL	0.5 ppm
Standard 3	0.1mL	1.0 ppm

IRON		
Standard	Volume of Stock Solution (1000 ppm)	Concentration of Standard Working Solution
Standard 1	0.025mL	0.25 ppm
Standard 2	0.05mL	0.5 ppm
Standard 3	0.1mL	1.0 ppm

Table 5: The volume of stock standard solution and its working standard concentration for lead and chromium

LEAD		
Standard	Volume of Stock Solution (1000 ppb)	Concentration of Standard Working Solution
Standard 1	10mL	100 ppb (in 100mL)
Standard 2 (QC)	1.25mL	25 ppb (in 50mL)

CHROMIUM		
Standard	Volume of Stock Solution (1000 ppb)	Concentration of Standard Working Solution
Standard 1	10mL	100 ppb (in 100mL)
Standard 2 (QC)	1.25mL	25 ppb (in 50mL)

Flame Atomic Absorption Spectrometric analysis of tap water samples for copper, zinc, iron, lead and chromium

The tap water samples (untreated and pre-treated) were analyzed by AAS instrument using the standard solutions prepared as described previously. All analyses were conducted under the standard conditions or parameters as described below:

Table 6: Standard AAS parameters for determination of copper, zinc, and iron (FAAS)

Parameters	**Copper**	**Zinc**	**Iron**
Wavelength (nm)	324.8	213.9	248.3
Slit (nm)	0.7	0.7	0.7
Relative Noise	1.0	1.0	0.7
Characteristic Concentration	0.077 mg/L	0.018 mg/L	0.11 mg/L
Sensitivity Check	4.0 mg/L	1.0 mg/L	6.0 mg/L
Linear Range	5.0 mg/L	5.0 mg/L	6.0 mg/L
Oxidant	Air/Acetylene	Air/Acetylene	Air/Acetylene
Oxidant Flow	17.0 L/min	17.0 L/min	17.0L/min
Fuel Flow	2.0 L/min	2.0 L/min	2.0 L/min